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# Development of a cylindrical type ultrasonic motor

Yasuyuki Katsube†, kazutaka Honma, Duala (FDK Corporation) and Jun Kondoh (Shizuoka University, Graduate School of Science and Technology)

## 1. Introduction

In recent years, the high-performance of a device in a mobile phone is realized by miniaturization and diversification of modules. For example, a new camera, which is improvement of a pixel, automatic focusing, and optical zoom module, is equipped. In addition, new functional devices, such as an HDD and Bluetooth, are planned as addition modules. Therefore, miniaturization of a module and decreasing electricity consumption are earnestly desired. For this purpose, development of miniaturized and little electricity camera module is required.[1, 2] We have examined practical use of the cylindrical type ultrasonic motor. Compared with an existing lens actuator, the feature of it is space saving and power saving. This motor was proposed by Kumada as a center of gravity turn type ultrasonic motor.[3] However, it has not been realized to practical use, because it is difficult to hold the cylinder element. In this paper, we describe relationships between holding method and fundamental characteristics of the motor.

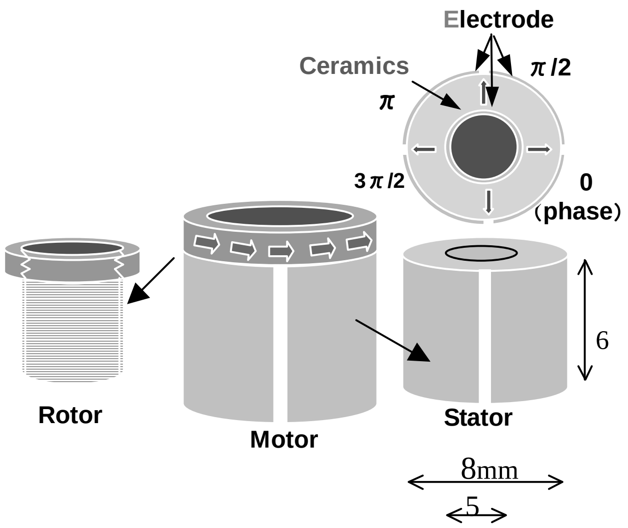


Fig. 1 Configuration of the developed motor.

## 2. Structure and Principle

Developed motor is shown in **Fig. 1**. The stator is the cylindrical-shaped PZT element, which is sandwiched between an inner electrode and four outer electrodes. The PZT material is P31 (FDK Corp., Kosai). The polling direction is aligned from the inside to the outside of the thickness direction. The rotor is the hollow tube with the brim, which is the friction plate. The motor is formed by inserting the rotor into the stator. The mode of vibration is the degeneration mode of the hollow cylindrical asymmetry vibration[4] and axial direction longitudinal vibrations. The vibration modes are excited with two electrical sources, which have + or –90 degrees phase shift. In the same manner as traveling-wave-type ultrasonic motors, the rotor turns through the frictional force. The excellent characteristic of the proposed motor is the point where element itself constitutes stator. Therefore, high Q-factor without loss is realized.

The second characteristic is simple constitution. The calculated displacement distribution of stator with a finite element method is shown in **Fig. 2**. There is a node of vibration in cylinder axis (Z) direction central part. We changed holding mainly on this node.

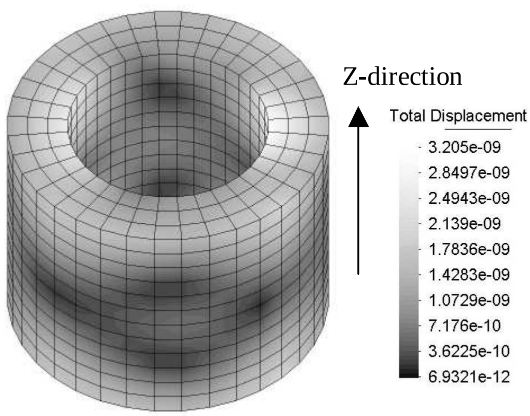


Fig. 2 Displacement distribution of stator.

## 3. Experimental Results

The relationships between holding method, displacement of a Z direction, and rotational speed were measured by only rotor weight. The holding width was assumed 15-50% of stator length mainly on a node. The holding strength was assumed as two kinds of the strength and weakness. The holding power was evaluated from the resonance admittance at a slight voltage (500mV) applied. A holding jig (see **Fig. 3**) is made of four pieces. Holding of the stator and electrical contact were performed by the jig.

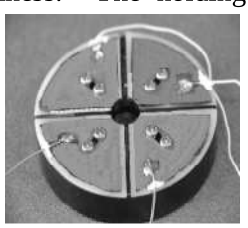

Fig. 3 A holding jig.

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marukatu@fdk.co.jp

Measurement block diagram is shown in **Fig. 4**. The electrical signals were applied to facing electrode pairs (A-C and B-D). The phase difference of the signals were 90 degrees. The applied voltage was 5V. Resonance frequency was determined from maximum current between the electrode pairs (DCc). We measured vibration of the Z direction using laser vibrometer. Then, the rotor was set and measured the rotational speed using a fiber sensor. In addition, cylinder, which is made of stainless (14 g), is inserted into the rotor. Cylinder diameter corresponds to diameter of hole in stator. Therefore, using this rotor, stable rotation is realized.

**Figure 5** shows the relationships between the resonance admittance and Z direction displacement (Z-displacement). The correlation coefficient is low (ca. 0.75). However, as resonance reduces when holding strength becomes strong, reasonable results were obtained. In other words, vibration is suppressed by the holding.

Maximum rotational speed of 1300 rpm was obtained at the Z-displacement of 0.6 μm, as shown in **Fig. 6**. Moreover, we found that there is high correlation of 0.9366 between rotational speed and Z-displacement. The rotational speed per Z-displacement 0.1 μm is 260 rpm. The center of gravity revolution radius of stator was calculated as 0.24 μm at the rotational speed 1200 rpm and driving frequency at 270 kHz.

## 4. Conclusions

Strength of holding is influenced by quantity of Z-displacement. We found that a linear relationship is established between Z-displacement and rotational speed. The rotational speed of 260 rpm per Z-displacement 0.1 μm is obtained.


**References**

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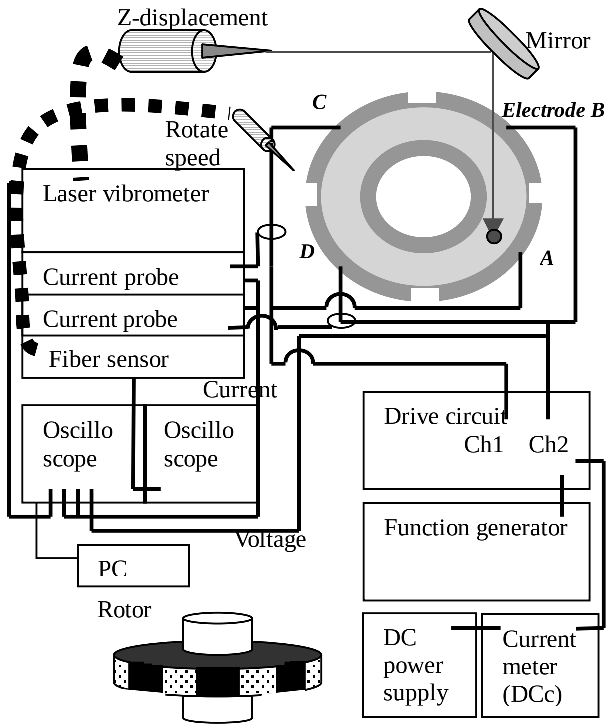


Fig. 4 Block diagram of motor measurement system.

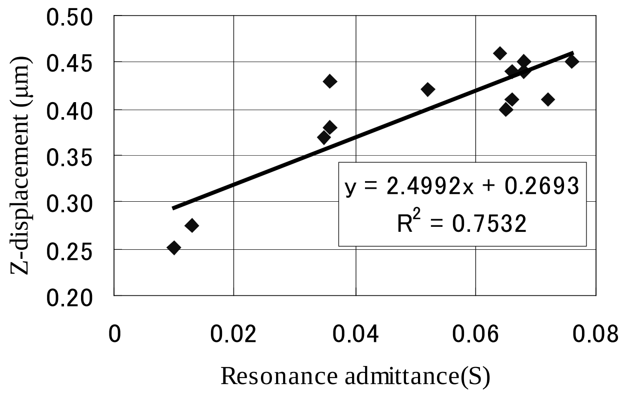


Fig. 5 Z-displacement as a function of resonance admittance at DCc of 70mA.

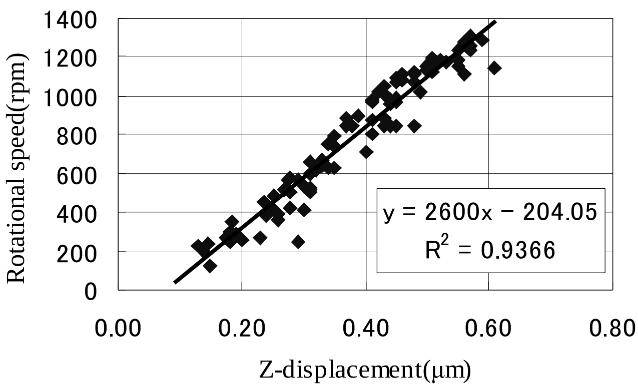


Fig. 6 Rotational speed vs. Z-displacement.